Marconi's Dramatic Moment on Signal Hill: A Retrospective Review

Part One

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One hundred years ago, Guglielmo Marconi (1874-1937), while situated atop Signal Hill, St. John's, Newfoundland, reported the reception of transatlantic wireless signals sent from Poldhu Point, Cornwall, on the Southern coast of England. The signals consisted solely of three brief clicks, representing the letter "S" of the Morse code, sent over and over again during the afternoon of December 12, 1901.

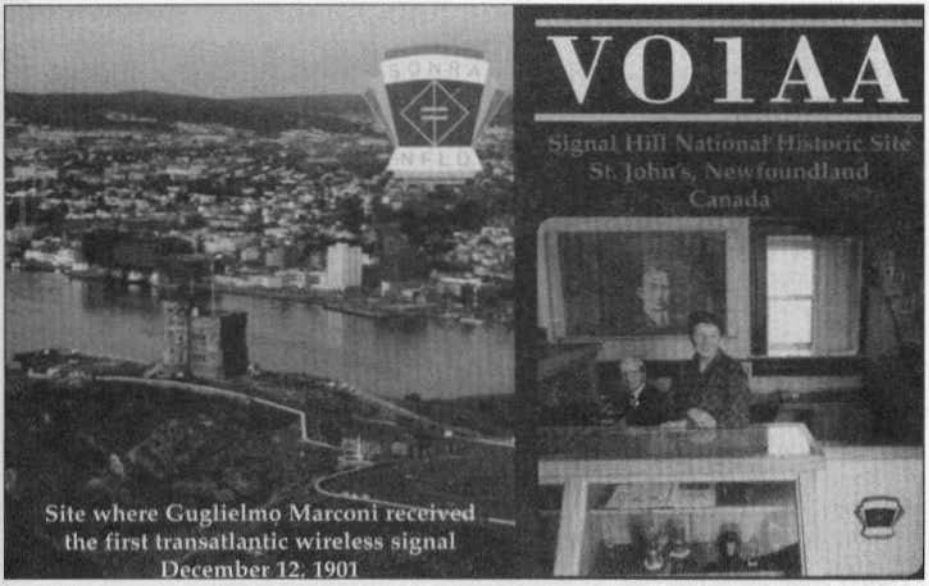
Marconi had conducted recently wireless transmissions across the English Channel and from coastal stations to nearby ships at sea. His efforts attracted considerable publicity and alerted entrepreneurs to the commercial potential of wireless. The transatlantic performance, however, heralded an illimitable leap into the future. The long-distance wireless transmission of electromagnetic waves represented an unforeseen dimension of physics-an extension of reality that illustrious scientists of the day, like Thomas Alva Edison, thought impossible. The worldwide reaction to the event was predictably one of incredulity and astonishment. Perhaps a comparable intensity of awe and excitement was attained subsequently when astronauts first walked on the surface of the moon; perhaps it will not be attained again until a spaceship carries humans to another planet.

I became a radio amateur as radio technology flowered around mid-century. Marconi's stunning 1901 exploit featured prominently in the folklore then current. My interest in it languished subconsciously for years thereafter, since the apparatus that he used—coherer receiver, 15-25 kilowatt spark transmitter, and ad hoc antenna designs—had little meaningful connection to the vacuum tube era in which I was participating.

A few years ago, my interest was revived when a trip to England provided opportunity for a visit to Poldhu point. I stood on the forlorn site where a radio shack once housed his spark transmitter, which in 1901 had been far and away the most powerful transmitter ever constructed. The site was on a promontory over 100 hundred feet above the Atlantic shoreline, which offered a view of the horizon that seemed half-way to Newfoundland.

My inquisitiveness thus kindled, I was motivated during August 2001, to visit St. John's, Newfoundland. The Province was in the midst of commemorating the one-hundredth anniversary of Marconi's transatlantic test. Children were being encouraged to fly kites, in symbolic replay of a Herculean aspect of the event (see Part III, below). Distinguished spokespersons were making speeches, less about Marconi's historical tests than visionary pronouncements about the next stages in wireless communications. Importantly, the curators of exhibits at Colonial Building, St. John's, where legislators once held their congresses, arranged cooperatively with the staff of Marconi plc, Chelmsford, England, to bring to Newfoundland for a temporary exhibit the original equipment that Marconi had used on Signal Hill.

A few weeks after he returned from St. John's, Marconi stored in boxes at



VO1AA—QSL card of the Society of Newfoundland Radio Amateurs (SONRA), whose members operate a commemorative (SSB) amateur station on Signal Hill.

Chelmsford the coherer and its accessories, which someone covered much later with cloth sheets. The diligence and persuasiveness of the curators paid dividends, because for one hundred years, successive generations of Marconi personnel in charge of the priceless heirlooms had chosen to prohibit historians, scientists, and citizens from examining them.

The artifacts brought to the Colonial Building were displayed in rectangular glass cabinets set on pedestals for viewing easily from several perspectives. The docents whom I met were justifiably proud that this was the first exhibit of the receiving equipment that Marconi had used on Signal Hill. The fact that it has been boxed and hidden from scrutiny explains why it has been described speculatively in the literature only with sketches and drawings-journalists and biographers had been denied access to pictures of the actual items. Since the artifacts were now were on public display and accessible for everyone to view free of charge, the gracious docents permitted me to photograph them through the glass of the cabinets. To assist me, they removed glare by turning off spotlights and closing curtains to exclude sunlight.

Initially, I intended this paper to be primarily one in which I shared with readers of Electric Radio my photographs of Marconi's receiving apparatus (see Part III, below). My intent was to augment the perspective provided already by the sketches and drawings. However, as I reviewed the circumstances associated with Marconi's formative years and his transatlantic tests, I encountered details that unfolded less lucidly than I anticipated. Therefore, I decided to present the pictures in the context of a discussion of both Marconi's emergence as a wireless engineer through 1901 and the incremental development of his apparatus. I describe transmitter evolvement from Hertz, Marconi, and Fleming and receiver evolvement through Varley, Hertz, Branly, Lodge, Popoff, Marconi, and Solari. I have

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divided my commentary into four parts: (I) Marconi's formative years; (II) Marconi's frenetic, accelerated professional growth in England; (III) Marconi's dramatic moment at Signal Hill; and briefly, (IV) Marconi's stature in history.

Part I: Marconi's formative years

Marconi's childhood in Bologna, Italy, was cushioned by prosperity. His father oversaw huge family farms and banking interests. His mother was a heiress from a wealthy Scotch-Irish family, who were whiskey distillers in Dublin. She grew up living in a castle and had come to study music at the Conservatory in Bologna, where she met and married his father. Marconi's boyhood residence was his father's four-story mansion, Villa Grifone, surrounded by acres of vineyards.

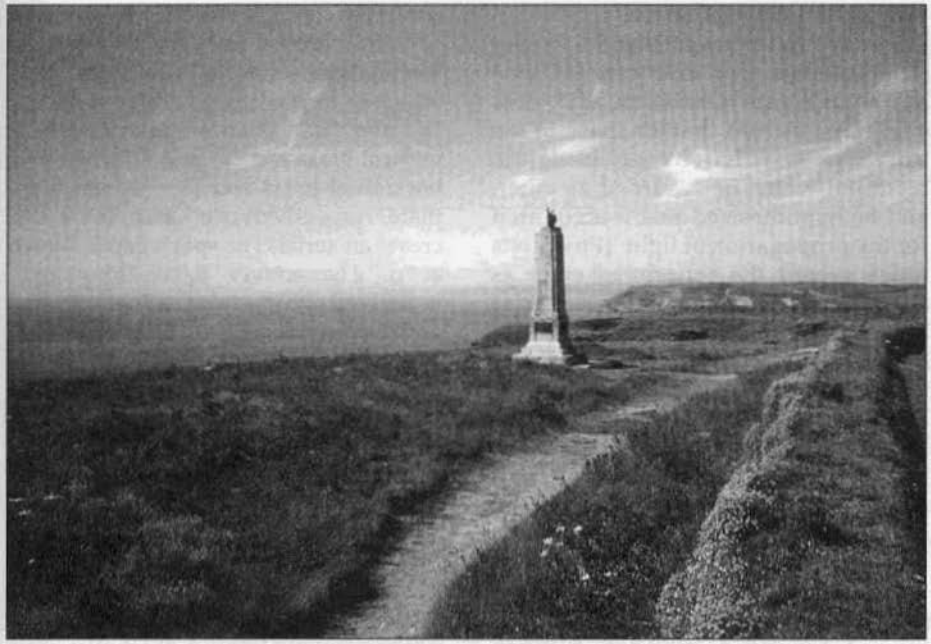
Marconi did not attend school with other children. He was tutored starting at age five until he was 14 years old. Reading books, especially about electricity, became his favorite pastime between five and ten years of age. Since the relatively severe winters in Bologna were distasteful to his mother, the family and tutor moved usually for a few months to warmer, seaside climates, like Florence or Leghorn. In Leghorn, when he was 13, he befriended an elderly former telegraph operator who was losing his sight. Marconi read to him, and in turn, the older man taught the boy the Morse code. Marconi's acquisition of code skills, at a youthful age, indicates an early interest in telegraphic communication. My belief is that the occasion was one of his more critical formative experiences. A few years later, when he began seriously to demonstrate wireless systems, skill with the Morse code facilitated his gaining knowledge hands-on as he operated equipment himself.

When Marconi was 14 years old, his parents enrolled him in a Florence Institute, where his favorite classes were in physics and chemistry. Marconi loathed the school, partly because years of solitary tutoring failed to prepare him for the rough and tumble activities of his peers. However, Marconi developed a life-long friendship with an older boy, Luigi Solari, who later assisted him in countless experiments, and notably, provided the coherer that Marconi used on Signal Hill to listen for transatlantic signals from Poldhu.

Marconi attended the Leghorn Technical Institute at age 15. His mother obtained this time the services of a teacher who provided for him private lessons in physics. The breadth of his knowledge expanded rapidly. He began to subscribe to physics journals, and he used volumes at the Institute to complement the relatively good collection of technical books in the library at the family estate. He was attracted especially to discussions of experiments. On one occasion, Marconi demonstrated Benjamin Franklin's proposition that static electricity could be drawn from a cloud in the midst of an electrical storm; he connected a bell to a zinc spear placed on the roof of the villa, leading it to ring when a thunder storm materialized.

Given the studious, young lad's intense involvement in physics, his mother arranged for him, at nineteen-years-of-age, to discuss his interests with a family friend, Augusto Righi, distinguished professor of physics at the University of Bologna. Righi appreciated Marconi's curiosity and dedication, and without requiring him to register as a student, he allowed him to borrow his books, attend his lectures, and perform experiments in his laboratory. Marconi spent endless hours pouring over books and conducting experiments; in the process he developed, as most good technicians do, a sophisticated, intuitive capacity in understanding how to make things work while not understanding the theoretical bases for why they worked.

Whereas most of the adolescents in



Monument erected in honor of Marconi at Poldu Point. The plaque reads as follows: "To commemorate the pioneer work done by Guglielmo Marconi and his research experts and radio engineers at the Poldu wireless station between 1900 and 1933. The Marconi Company presented this historic land to the National Trust. Some six acres of cliff land were given in 1937 and forty four acres behind the cliffs on which stood the station and masts were given in 1960."

Bologna were expected to work to augment allowances, and perhaps aid their families, Marconi's family resources afforded him the luxury of being a self-educated student, unfettered by financial constraints. Throughout his formative years, his mother had taught him English and inspired him to concentrate, to learn, and to follow his inclinations, wherever they might lead him. She encouraged him to elevate his dreams and aspirations to higher and higher planes; thus, he became literally a "son of destiny;" he acquired an exalted sense of self-confidence, and as an adult, consecutively more lofty visions led him to address seemingly unattainable goals. Simultaneously, his father neither interfered with his son's solitary activities nor discouraged him. However, his father exerted as much influence as his mother upon his character; via subtle discussions, he imbued his son with an acute awareness of entrepreneurial corollaries-to be certain that his every undertaking represented a sound, profitable investment.

In the summer of 1894, during his twentieth year, his mother sent Marconi in the company of an older brother, to the Italian Alps for a vacation. She hoped that his gregarious brother would introduce him to outdoor sports and evening festivities, thus tempering his reclusion. The stratagem failed. One day, while in the Alps, Marconi read an obituary of Heinrich Hertz who had died prematurely that year at only 37 years of age. The article described how, six years earlier, in 1888, Hertz had demonstrated empirically the principle that "electric waves" could be

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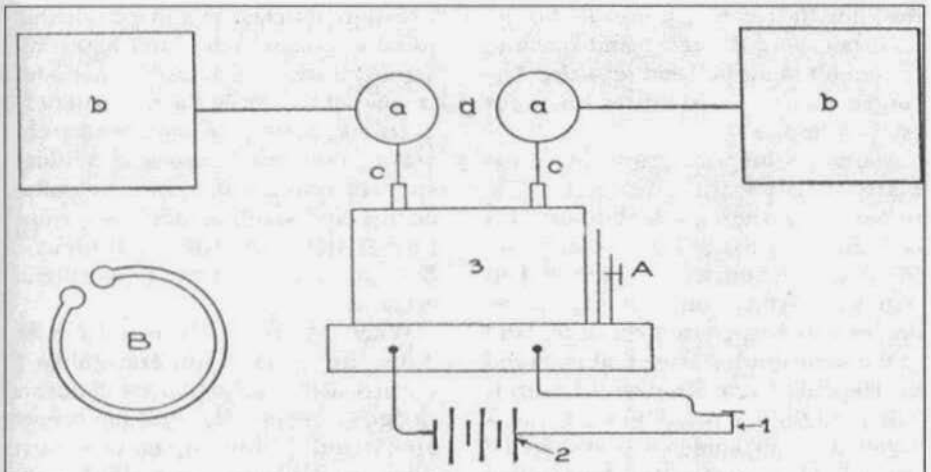
propagated through space.

Hertz drew upon a substantial variety of precedents. For example, a Dutch mathematician, Christian Huygens suggested in 1678 that all space in the universe is filled by an invisible medium, which he regarded as ether, and he hypothesized that it accounted for the propagation of light. [Physicists today regard the concept of ether as superfluous.] Almost two centuries later, in 1832, the British genius, Michael Faraday, who contributed extensively to the science of electricity, supported Huygens' theory. Faraday stated that he believed that some form of vibration propagates both light and electromagnetic waves through the atmosphere. Faraday also offered a laboratory demonstration of the "induction coil;" that is, if a low-voltage is delivered to a coil of a few turns wound around a cylinder, a much higher voltage is produced at the ends of a second coil of many turns, when it is wound over the first coil. Consequently, should the ends of the second coil be brought close together, a relatively large spark will ensue. Following Faraday, a British mathematician, James Clerk Maxwell, developed in 1867 a precise, comprehensive mathematical formulation in which he postulated that both light and electromagnetic waves travel similarly through space at a speed of 186,000 miles per second.

Hertz set out to design a laboratory experiment that would both create and detect electromagnetic waves. His primary objective was to demonstrate that the waves travel through space. In developing parameters for his apparatus, he incorporated serendipitously what were to become the three essential components of a wireless system—transmitter, aerial(s), and receiver. Figure 1 illustrates Hertz' system. [Thom-Collins, 1908, Part II, p. 5). The sending mechanism "A", or "exciter," as he named it, is comprised of "1" a key, "2" a battery, and "3" an induction coil. The high tension terminals are connected to an "oscillator," which is formed by two brass spheres, "a" and "a." Each is supported by a vertical brass rod "c" and attached by a horizontal brass rod to a square brass plate, respectively, "b" and "b," which create an aerial. The spark-gap is shown at "d." The receiver "B," or "resonator," is derived simply from a loop of wire, with its ends affixed with tiny balls, which are brought close together. Hertz hypothesized that when the exciter generates a high-voltage current, a spark will leap from one oscillator ball to the other; electric waves will then be emitted, and via wireless, a small spark will jump across the open ends of the resonator.

Hertz' confirmation of Maxwell's theory was widely disseminated throughout the scientific world. Excited physicists replicated it easily. The primitiveness of his detector, however, narrowed for a time his extraordinary demonstration to the status of a mere novelty. The wire ring that Hertz used as a detector required too much energy from his oscillator to affect it more than a few feet away.

Physicists were initially pessimistic about whether the detector could be improved. However, an English railroad technician, S. A. Varley, in the 1860s, sought to protect telegraph lines from lightning, and in discovering by trial and error the mechanism he needed, he produced inadvertently the first wireless detector. Varley packed a block of wood loosely with carbon and tin filings, tied one end of the filings to a telegraph wire and the other end to ground. He found that the loose filings were highly resistant to the passage of electricity, so that when the block was in the circuit, the wire was insulated from ground; however, the filings adhered in the presence of lightning, and in this low-resistance condition, conducted the lightning to ground. After the lightning passed, the



Hertz's Electromagnetic Wave Method.

Fig. 4.

Figure 1: Hertz's electromagnetic wave apparatus

filings returned to their loose state and again insulated the telegraph wire from ground.

Varley had solved a substantial problem, and post-Hertz physicists were relieved when they recognized that he had created the first relatively effective wireless detector, for only in the presence of an electromagnetic wave—lightning being comparable to a man-made spark—would the device conduct current. Professor Edouard Branly, a French physicist was first to convert Varley's wooden device into a wireless receiver. In 1890, he filled a thin glass or ebonite tube, a few inches long, with iron filings with which he detected waves from a Hertzian oscillator at about 65 feet. Branly used an adjustable copper plug at each end of the tube. He found, with tension against the loose filings from the plugs, that reception of an electromagnetic wave caused the filings to adhere, that is, change from relatively higher to lower resistance, and thereby, conduct current, which he registered on a galvanometer in series with a battery across the plugs. Furthermore, Branly found that he could loosen the filings again instantaneously by tapping the glass tube with the end of a pencil.

Four years later, Sir Oliver Lodge, professor of physics at Liverpool, succeeded in 1894 in detecting Hertzian waves several hundred feet with the Branly receiver. He fitted the tube with a clock mechanism to jar the particles loose automatically. Lodge called the device a "coherer" in that wireless waves caused the filings to cohere. In 1895, about the time Marconi's interest in wireless flourished, Alexander Popoff, a Russian physicist made significant improvements in the Lodge coherer while endeavoring to develop a warning device for lightning storms. Popoff was first to use an aerial and ground system, a technique that Nikola Tesla in 1883 had described in published lectures (Cheney, 1981, p. 69). He also incorporated a "decoherer tapper" that was controlled directly by the wireless impulses. When the latter lowered [changed] the resistance of the coherer, conduction closed the circuit of a battery operated-relay, which in turn, activated a bell and a clock-driven recorder. The bell striker tapped the coherer leading

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the filings to decohere [raise resistance], thus releasing the relay and opening the circuit to the bell and recorder. The contrivance was now in readiness for another impulse.

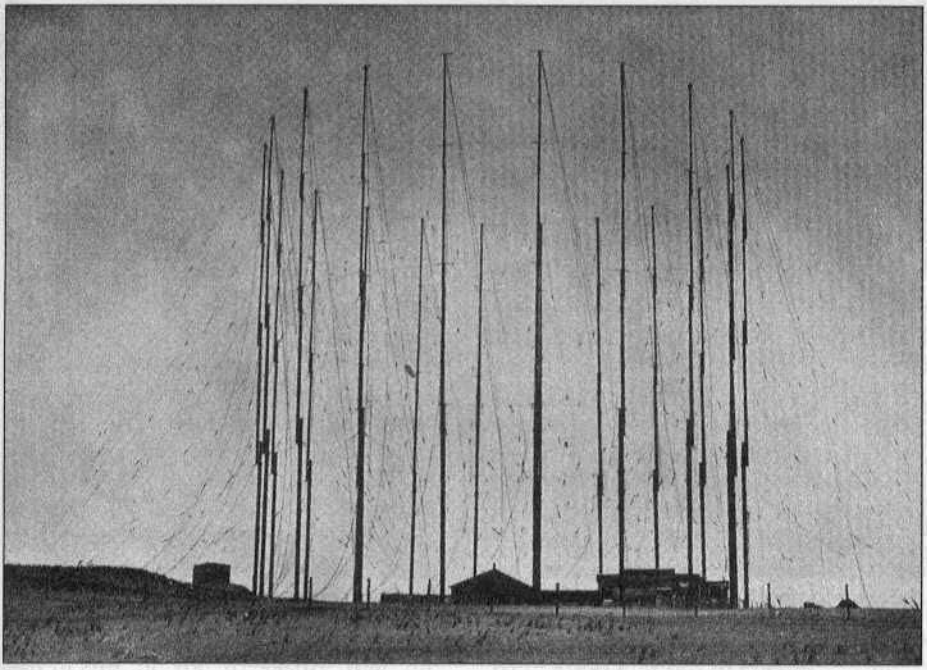
Marconi's biographers assume that Marconi first learned of Hertz' epic research when he read his obituary. This is logically possible, but barely so. Marconi's mentor, Professor Righi had published articles on Hertzian waves; one of which appeared coincidentally in the same journal issue that included the Hertz obituary (Kreuzer & Kreuzer, 1995). Righi regarded wireless as a noteworthy phenomenon, but shared a belief held by many other laboratory scientists of that period that it had no practical significance. Given that Professor Righi was actively researching Hertzian waves, and that Marconi was under his direct tutelage, it is virtually inconceivable that the widely read young man had not before learned something of Hertz' wireless experiment, and the subsequent efforts of Branly and Lodge to improve Hertz' primitive detector.

Perhaps during the ensuing six years between Hertz' demonstration of wireless and his death, Marconi encountered only isolated commentary about the advent of wireless. Since Righi regarded the phenomenon as inconsequential, an impressionable Marconi may have dismissed it cursorily, too. However, when fragmented insights merged into a sweeping vision after he read Hertz' obituary, Marconi's intuition persuaded him that telegraph messages could be sent and received over great distances—once the deficiencies in Hertz' wireless apparatus were remedied. Vast benefits to humankind and enormous commercial gain might then be realized. Messages sent by wireless would be less expensive per word than those sent across telegraph lines; costly submarine cables would become superfluous; maritime wireless would permit ships to be in contact with land bases, and significantly, save lives by facilitating rescues at sea. From the moment of his percepts, Marconi's modus operandi was that of a man possessed! Within a span of only seven years, relentless energy and single-mindedness would propel the unregistered student in Bologna from obscurity to worldwide acclaim.

When Marconi returned from the Alps, he worked indefatigably to reconstruct Hertz' exciter-oscillator and Lodge's coherer. He took the coherer apart and following endless tests discovered that a mixture of 95% nickel and 5% silver, ground to dust, made the best filler. Next, he exhausted the air from the tube and found that a vacuum improved both its sensitivity and reliability. Following a few months of tinkering, he connected across it a Morse sounder and battery in series, placed the coherer about 200 feet from his oscillator and asked his father to listen for a series of clicks. Marconi assured him that with further improvements, messages in Morse code could sent commercially over long distances. He acquired his first investor when his father advanced funds to purchase supplies for additional experiments.

Marconi was thankful for his father's support, because he was convinced that by intensifying his research he would eventually perfect a commercially viable communications system; however, he worried that someone would surpass him. Years later, he is reputed to have said: "My chief trouble was that the idea was so elementary, so simple in logic that it seemed difficult to believe no one else had thought of putting it into practice" (Jolly, 1972, p. 23; Tarrant, 2001, pp. 21-22).

Marconi's concerns were unfounded, truth-be-told, because he was unacquainted with the academic world in which his competition functioned.



Circle of masts erected at Poldu and Cape Cod, respectively, for the transatlantic experiment.

Academic scientists prefer to advance theorems and principles rather than indulge in uncertain applications. They work tediously in university laboratories, on a single issue at a time usually, to be certain that the explanations they set forth are accurate and replicable. They are trained traditionally to draw conclusions conservatively; they are neither expected nor encouraged to think in terms of humanitarian and commercial implications. They are disinclined to ponder either impulsively or speculatively. Moreover they must often fulfill other tasks associated with teaching and administration, and they may have limited financial resources for research. For example, both Branly and Lodge, respectively, were on the cusp of creating wireless systems. However Branly said reflectively in 1927: My difficulties have always been tremendous. I have never been well off..." (Coe, 1943, p. 26). Lodge also reported in 1923: "I was too busy with teaching to take up telegraphic or any other development. Nor had I the foresight to perceive what has turned out to be, its extraordinary importance to the Navy, the merchant service, and, indeed, land and war service, too" (Hawks, 1927, p. 242).

Marconi, in contrast, had spent his adolescence training himself to be a resourceful, skillful, applied technician in physics. His strengths were in taking the products of other and improving upon them. He was unconstrained by laboratory regimen and free to pursue promising ideas, trust his own judgment, and persist against daunting odds. He was guided by grand-scale visualizations, and from them, derived inspiration to strive for long-range goals. Importantly, Marconi's family and their entrepreneurial and investor connections guaranteed access to money virtually whenever he needed it. Nonetheless, Marconi was anything but

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evening, 'The Smoking Room.' For longer than anyone liked, an elderly gentleman, smoking a pipe, delivered a bunch of down-home philosophy and humor. I suppose the best way to describe the program is as a bad imitation of Will Rogers. After the 'Smoking Room' we watched a movie of a symphony orchestra as they 'fiddled' away for one hour.

Program material made little difference. We waited anxiously every evening for the TV station to 'sign on.' Sometimes during the day we left the set on with nothing but a test pattern to see.

Very soon after Oklahoma City came on the air, KOTV in Tulsa, Oklahoma began operation on a nightly schedule. Tulsa, only 100 miles away, came in much better even with their small 16KW transmitter, and a roof-mounted antenna. The roof was on the 'Phil tower,' the tallest building in Tulsa at the time. If I remember correctly, the antenna was some 350 feet above ground. Today, the Philtower is lost amid a cluster of much taller high-rise office buildings. At last, we could depend upon some sort of picture almost every evening. It seems TV at long last was finally coming around that long predicted 'corner.' ER

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a mannequin shaped by external forces; during his formative years he developed a strong will to succeed, attained a sound knowledge-base in physics, acquired an astute understanding of applied technology, and significantly, as a consequence of his family background, learned social graces that enabled him to interact with ease in the company of persons at all levels of society-kings, queens, eminent scientists, lowly laborers, etc.

Since no one on the horizon appeared poised to dash his dream, Marconi toiled vigorously in 1894-1895 to improve his apparatus. After making changes incrementally to the coherer, he began a step-by-step reconstruction of Hertz' oscillator. First, he substituted relatively large metal plates for the ones Hertz had attached to the spark balls, and found that the distance a signal could be sent increased. He then fastened one plate on top of a tall pole and buried the other in the ground-following Tesla and Popoff's concept of a basic aerial and ground. As the pole went higher and higher, signals could be sent farther and farther. He added also an aerial and ground to the coherer and again circumstances improved. Marconi's somewhat imprecise observations led him to work from the assumption that "the energy of electromagnetic waves did not diminish in intensity when the distance was increased if the length of the aerial wires were increased as the square [root] of the distance, that is, by doubling the height of the wires the waves would be transmitted four times the distance, the initial energy remaining the same" (Thom-Collins, 1908, Part II, p. 13).

The day arrived, late in 1895, when Marconi was regularly transmitting a few miles to his coherer. Although his apparatus was still rudimentary, he decided to ask the Italian government to fund a program of comprehensive research. The Italian officials denied his request, but suggested, given the potential of wireless in ship-to-shore communications, that he offer his system to authorities in England, where maritime activities are much greater than in Italy. Marconi's mother seconded the idea, began preparations for the two of them to move immediately to London, and wrote to friends and relatives in Ireland and England to announce their coming. ER

Ed. Part 2 next month.

Marconi's Dramatic Moment on Signal Hill: A Retrospective Review

Part Two

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Part II: Marconi's frenetic, accelerated professional growth in England

On February 2, 1896, twenty-one year old Marconi arrived with his mother in London, where they were met by Marconi's cousin, thirty-year old Henry Jameson-Davis, a socially prominent young engineer and businessman. He had rented for them a quiet house in which Marconi could develop his apparatus. Marconi's wireless system as of early 1896, the one that he brought to England with him, is shown in Figure 2 (Fleming, 1919, p. 452). His transmitter was comprised of a key "K", batteries "B", induction coil or transformer "I", oscillator (spark balls) "S", aerial "K1", and ground connection "E". His transmitter was identical schematically to that of Hertz.

Marconi's receiver included an aerial "K2", ground connection "E", revised Branly/Lodge coherer "C", choking coils, relay "R", battery for relay "B1", Morse inker "M", and battery for inker "B2". The "choking coils" are in the circuit to prevent electromagnetic waves passing through the coherer, variously denoted in different sources as "electric waves," "oscillations," "impulses," and simply "waves," from wasting energy in the relay coils "R." They also prevent impulses that originate at the contacts of the relay from affecting the coherer. When oscillations change [raise] the conductivity of the coherer the circuit of battery "B1" closes to operate relay "R". When the relay closes, battery "B2" starts the tape rolling on the Morse inker, which provides a permanent record of the wireless impulses on a tape. Battery B1 also serves importantly as a benchmark for adjusting the coherer for maximum sensitivity. The plugs of the coherer tube must be set so that filings become agitated and begin to cohere at a voltage just slightly higher than that of the battery—otherwise the battery itself will pack the filings. Although relay "R" may draw less than one milliampere of current, even this tiny amount is too gross for setting the sensitivity of the coherer. Therefore, for purposes of adjustment, a galvanometer or telephone receiver, which produces an onset and offset click with each electric wave, is usually either substituted for the relay or placed in series with it (Crane, 2000; Fleming, 1919, p. 373).

Fleming (1919, p. 377), with commendable frankness, observed that "the arrangements of Marconi, though admirable, require some dexterity to manage them." For example, the tapper must be set delicately to deliver rapidly a series of blows of just the right strength to keep metal filings in the coherer constantly loose. When oscillatory sparks are transmitted via key for a short period of time, a "dot" is printed on the tape; when sparks are longer, a dash is recorded. If the tapper is too slow or too fast in restoring the coherer in respect to the sending speed of the telegraph operator, the wireless dots

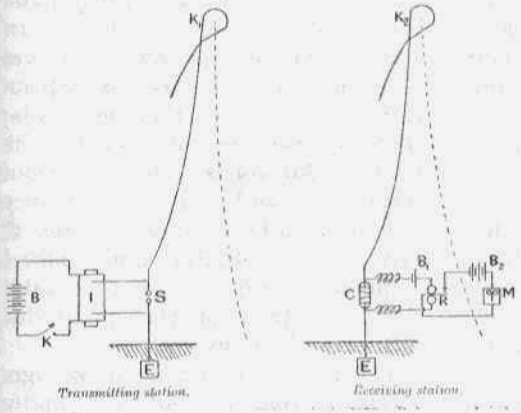

Figure 2

and dashes will be garbled, the Morse alphabetic code will be unreadable, and the message uninterpretable.

Unfortunately, during English Customs, a careless agent reduced Marconi's precious apparatus to rubble. Marconi struggled during the spring of 1896, as he turned 22 years-of-age, to reconstruct the equipment. He prepared also a preliminary description of it for submission to the London Patent Office, June 2, 1896. He followed up on March 2, 1897, with complete specifications and drawings, and on July 2, 1897, a patent was granted to him.

Marconi met in July 1896, with Mr. William Preece, Chief Engineer of telegraph and telephone networks of the English Post Office. Preece had dabbled unsuccessfully with a crude form of wireless, and he was familiar with the Branly/Lodge coherer. He was thus astounded to discover how meticulously Marconi had configured improvements empirically in his coherer to maximize its sensitivity, such as evacuating air from the glass tube and positioning its plugs to create an adjustable gap filled with a precise quantity of space and metal filings.

Perhaps Preece was even more amazed when Marconi operated his coherer. We know that Marconi's industrious manner impressed him and that he considered the demonstration to have been spectacular. Indeed, Preece offered the young man the use of his laboratory, and he served as his sponsor in arranging a series of demonstrations in 1896 and 1897 for officials and engineers of the British Postal Telegraph system. Moreover, a technician who worked in Preece's laboratory, Mr. George S. Kemp, was assigned to assist Marconi. Shortly thereafter, Kemp left Preece to work for Marconi; the association initiated a close, personal relationship that prevailed until Kemp's death in 1933.

Regrettably, neither Preece nor Marconi regarded the demonstration as having historical significance, for exactly what occurred has never been described. However, given Marconi's eagerness to obtain Preece's backing, he must have explained the characteristics of the coherer in considerable detail. Specifically, to show Preece the breadth of its capability, he would have indicated its use in: (1) receiving and recording with a Morse inker, (2) copying Morse code with a sounder, and (3) copying weak signals with a telephone receiver.

After having set up his spark gap exciter, possibly in another room, Marconi might have asked Preece to settle himself comfortably in front of the coherer. First, Marconi would have connected the coherer to the Morse inker, as shown in Figure 2. As Marconi pressed briefly the key of his exciter, Preece would have seen the inker tape register a "pip," signifying a "dot." Marconi may have said next that he would draw upon his code skill to send a message; Preece, who doubtless also knew the Morse code, could read

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visually the message in code pips off the inker tape. Marconi surely paused to indicate to Preece that copying code with a coherer is touchy almost to the nth degree. "Why is this so?" Preece might have asked. Now, Marconi probably seized the opportunity to reveal how coherers function. The coherer, he would have said, operates as a variable resistor through three stages in each time segment between the onset of an oscillation and the packing of the filings, e.g.: (1) as an insulator-possessing extremely high resistance when metal filings are loosely packed, (2) as a detector when an electromagnetic wave causes a change in its resistance from higher to lower—as metal filings start to cling together, and finally, (3) as a low-value resistor—when the filings become so tightly packed that changes from impulses to even lower resistances are impossible.

Marconi would emphasize that the coherer works as a detector only when oscillations cause it to change the resistance of the metal filings, and therefore, the automatic tapper is a convenient accessory that keeps it from disabling itself in the form of a simple resistor. The tapper moves swiftly, he would note, because it is adjusted to keep filings loose all the time.

Second, Marconi would have substituted a Morse sounder for the Morse inker in order to show Preese another facet of the coherer. Only clicks would be heard as a message is sent. Preece would find the situation familiar, for wire telegraph operators assign meaning to double-clicks to distinguish dots and dashes. The sounder onset click is much stronger than its offset click. A telegraph operator must be skilled in distinguishing between them before a message can be understood. The time interval between the two clicks is relatively short for "dots" and the time interval between the two clicks is relatively long for dashes. Since each letter of the Morse code is comprised of a unique combination of dots and dashes, a key operator must send every element of a combination via a separate impulse, each of which produces a distinct onset and offset click on the sounder. Marconi undoubtedly would have followed the convention of telegraphers by sending in series the letter "V" (dot, dot, dot, dash) to acquaint Preese with the time values that he would be using to separate dots, dashes, and spaces.

Third, to demonstrate weak signal reception, Marconi would have omitted all accessories except that he would connect a telephone receiver and battery in series across the terminals of the coherer. He would have pointed out to Preece that a fairly strong electric wave from a spark gap transmitter is necessary for controlling even a sensitive relay, and in turn, operating accessories. Even a very weak signal, on the other hand, will produce a click-buzz-click in a telephone receiver. Preece probably began to listen intently, but he would have heard nothing—the telephone receiver would have been silent-no static, no noise, no sound-nothing—providing that electrical impulses were not brewing during a thunder and lightning storm outside. When Marconi pressed the key, Preece would have heard a strong click in the telephone receiver followed by a buzzing sound generated by the arcking of the sparks, and finally, a feeble click when the key is lifted. A minimal use of accessories is necessary, Marconi would affirm, for weak signal reception, but the coherer no longer has an automatic tapper available to keep it restored and no capability for recording messages.

Marconi would summarize his presentation for Preece by stating that the coherer is inherently delicate and must be constructed precisely for reliable reception. Since a coherer will pass only a few impulses before it needs

another tap to loosen packed filings, the receiving operator must be exceedingly skillful to avoid missing part of what is sent. The task of copying weak code signals by wireless is especially tedious and fraught potentially with errors, because hand-tapping replaces the automatic tapper. Marconi could also state confidently that well-trained, traditional telegraph operators make easily the transition from wires to wireless and that many of them are eager to join him in conducting experiments.

Marconi's subsequent demonstrations for professional engineers were attaining noteworthy distances by late 1896, and they were beginning to attract media attention. To mitigate curiosity and publicize the viability of wireless, Preece arranged for a free demonstration at Toynbee Hall, at which Marconi walked around the auditorium carrying his coherer connected to a doorbell; whenever Preece pressed a telegraph key, the ensuing electric wave would activate the bell.

As word of his exploits spread, Marconi reached his 23rd year, and not surprisingly, became an intriguing, eligible bachelor. Prestigious hostesses sought him as their guest at London dinner parties. Marconi, however, regarded the elegant parties as a waste of time; he distained the small talk about wireless that guests expected of him. Speculators also approached him to sell the rights to his wireless system, but he brushed off their overtures since he was convinced more than ever that wireless was on the verge of becoming a tremendous commercial resource. He chose, therefore, to work on his apparatus by spending the winter of 1897 in semi-seclusion (Marconi, Degna, 1962).

Meanwhile, questions arose concerning the validity of his patent. Did his wireless system really qualify as a new invention? What had he contributed beyond the familiar work of others? Critics argued that his spark-gap transmitter was essentially a variation of what Hertz had conceived and his coherer incorporated features of Branly, Lodge, and Popoff. Thus, they looked upon his vaunted patent as flawed—as merely an abstract application of accomplishments not really his. Marconi and his supporters, nonetheless, believed that clearly he had perfected a doable wireless system for telegraphic communications. Thanks to his striking upgrades of the coherer, spark-gap transmitter, and aerial, Marconi had advanced prospects for wireless communications much farther than had anyone else. Awareness of the progress that he had made surely fortified his belief in himself and inspired him to redouble his effort to outshine his competition. Nevertheless, throughout his life, whenever he was proclaimed to be the inventor of wireless or radio itself, he would demure, insisting that he had invented only a workable system of wireless communications.

Hindsight reveals that Marconi's sweeping patent, purporting to cover all aspects of wireless communications, failed to protect his interests as he had hoped. It was interpreted narrowly to cover wireless mainly in respect to aspects of spark-gap transmissions and coherer receptions. Various alternative systems of wireless telegraphy were arising in Germany, in the United States, etc. for which patents were being issued. Marconi soon realized that his patent was rapidly losing its force. He recognized, 1897-1898, that successful ventures in wireless would be determined not by fiat but by whether he could best his competition in offering commercially effective and profitable wireless products.

As Marconi aimed in successive demonstrations to communicate at greater and greater distances, an

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asymptote approached. Aerial heights had practical limits and 250-500 watts of spark was about all that could be produced from batteries. Hence, Marconi focused once again on his coherer. He experimented with a Faraday induction coil in an attempt to amplify at the coherer weak signals reaching the aerial. The primary of his improvised coil consisted of a few turns of wire, one end of which was connected to the aerial and the other, to ground. The secondary of the coil, with many more turns, was connected across the coherer (Blake, 1928, pp. 108-109; Coe, 1943, p. 91). After considerable tinkering, Marconi was able to induce a stepped-up signal in the secondary coil, and thereby, enable the coherer to detect signals it had missed before. The basic design of the coil was named "jigger," maybe because Marconi jiggled with several manifestations of it in his effort to improve it; however, sometime around 1899 the coil was named the "Billy coil," perhaps in an affectionate deference to his English nickname.

Marconi's cousin, Henry Jamison-Davis, proposed to him in April 1897, on roughly his 23rd birthday, that a company be formed to develop and market his wireless system. Marconi figured that he now needed an infusion of about $100,000 [in 1900 dollars] to support his research. Therefore, on July 20, 1897, Marconi established "The Wireless Telegraph and Signal Company Limited." The Company paid Marconi roughly $40,000 in cash, plus 60,000 shares of the 100,000 shares issued at roughly $4.80 per share (Bussey, 2000). The balance of the 40,000 shares was put on the market for public subscription. Family members in Ireland, Italy, and England purchased most of the stock. On February 23 1900, at the urging of Marconi's father, the name of the company was changed to "Marconi's Wireless Telegraph Company, Ltd" (Kreuzer & Kreuzer, 1995, p. 22).

Marconi participated in demonstrations at breathtaking pace between July 1897 and December 1899. One of them involved communicating 11-1/2 miles from a land base to an Italian Naval warship at sea, after aerials at both sites were raised to 100 feet (Coe, 1943; Krezuer & Krezuer, 1995). Another demonstration, of which Marconi was particularly proud, occurred in 1898 when he established communications between Queen Victoria on the Isle of Wight and a yacht anchored about 7-1/2 miles away, where her eldest son, the Prince of Wales, was recuperating from a leg injury. Marconi attained from the venture immense stature in the English press.

On March 27 1899, Marconi sent and received signals successfully across the English Channel. He visited Dublin, July 28 1898, to make live reports on the progress of a yacht regatta, and repeated the feat, October 16 1899, in reporting on the America Cup races for the New York Herald. The events reaped expanded international recognition for Marconi and stimulated insatiable public interest in wireless communications.

While in the United States for the races, Marconi demonstrated his wireless technology for the U. S. Navy and Army. He had communicated distances of 80 to 100 miles between land stations and ships for the British Navy, and in America, he managed to send messages 60 miles. The military services, however, were disillusioned upon learning that transmissions sent simultaneously would interfere with one another. They rejected his overtures summarily.

Marconi was brought up short by the confrontation. The U.S. military had exposed a serious problem with his untuned wireless system. His apparatus was wholly unselective, and interference was becoming a major inadequacy as transmitting and

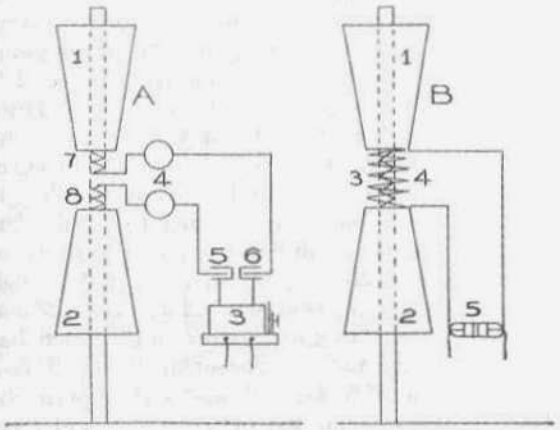

Figure 3

receiving stations proliferated. The dilemma was compounded by two complementary problems: (1) how to tune or synchronize a spark-gap transmitter and a coherer to be on the same wavelength, and (2) how to operate on different wavelengths so as to avoid interference.

Marconi attacked the problem in his usual manner. He investigated the work of others to ascertain whether a product had been invented to address them. He was heartened to learn that in 1897 Sir Oliver Lodge, of coherer fame, had invented a means of regulating or tuning the wavelengths of spark transmitters and coherers. Marconi was less thrilled to learn that Lodge had patented his technique with the title: "Improvements in syntonized telegraphy without line wires." Lodge used the term "syntony" to signify when two tuned circuits are resonate with one another. He recognized that the wavelength of a circuit is influenced by both "capacity" and "inductance," and he described a mechanism for adjusting the two factors in both transmitting and receiving circuits.

An overview of Lodge's system of syntonic tuning for a spark gap transmitter is shown on the left in Figure 3 (Thom-Collins, 1908, Part II, p. 25). Lodge developed two conical, horn-shaped radiators with a single rod or wire through each of their centers "A-1" and "A-2" to vary capacity. The cones are attached at their narrow ends, via the rods or wire, to an aerial and ground, respectively. Next, Lodge connected each terminal of the induction coil "3" in series with an adjustable Leyden jar condenser "5" and "6", also for varying capacity, and a spark ball "4" to one end of a spiral coil "7" or "8". The cones are charged by induction coil "3", and discharged through the spark gap "4". Each Leyden jar consists of metal foil sheets on the inside and outside of a glass jar. Each interposed inductance, "7" or "8", between the spark balls "4" and the cones is usually a spiral of a few turns. The spiral coils are squeezed or lengthened to vary their inductance values.

An overview of Lodge's syntonic system for the coherer is shown on the right in Figure 3. The receiver "B" is comprised of two similar capacity cones, "B-1" and "B-2." The two are connected through the primary of an induction transformer "3", whose secondary "4" is attached to each terminal of the coherer "5". As Lodge showed, transmitters and receivers so equipped may be set to operate on different wavelengths. Moreover, he also showed that they will resonate at the same wavelength when syntonized.

Marconi recognized that Lodge's system exemplified the basic principles of tuning, and he recognized, too, that a less wieldy mechanism had to be devised before it could be put to practical use. Therefore, after several months of experimenting, he introduced proudly in 1899 his version of Lodge's

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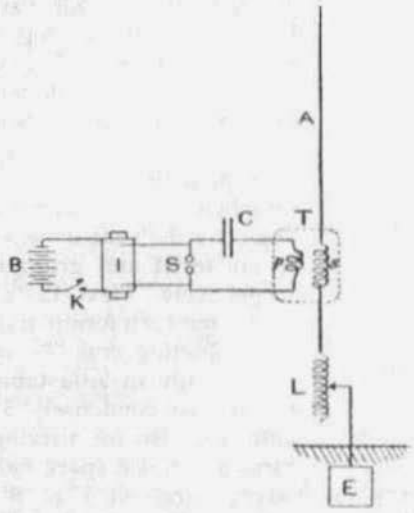

Figure 4

"syntonized" circuits. The design of his transmitting apparatus is shown in Figure 4 (Fleming, 1919, p. 464). First between one terminal of the oscillation transformer "T" and ground connection "E", he inserted adjustable induction coil "L". The secondary "s" of transformer "T" is connected between aerial "A" and "L". One side of the primary "p" of "T" is connected directly to a spark ball. The other side is connected through an adjustable Leyden jar condenser "C" to the other spark ball. The spark balls are connected to the secondary terminals of an induction coil "I". The primary of "I" is connected to a battery "B" in series with the key "K". By adjustment of variable inductance "L" inserted between the ground and the secondary circuit of the oscillation transformer and by varying the capacity of condenser "C" in the primary circuit, the two circuits may be brought into resonance with each other at different wavelengths.

Marconi's version of a system of syntonic reception with a coherer is shown in Figure 5 (Fleming, 1919, p. 465). The aerial "A", which is shown as terminated in a plate "f1", is connected to an adjustable inductance "g1", which in turn, is connected to ground "E" through the primary of an oscillation transformer "j1". The terminals of "j1" are connected by a small sliding condenser "h". The secondary of the transformer "j2" is cut in the middle, and a condenser "j3" is connected to the inner terminals. The outer terminals of the secondary of transformer "J2" are connected through two small variable inductances "g1" and "g2" to the coherer "T1" which has adjustable condenser "h1" across it. Two choking coils "C1" and "C2", respectively, are connected between "J3" and relay "R". A battery "B" is inserted between "C1" and relay "R" for operating the latter. When the variable condensers in the circuits are in resonance or syntonized with one another, the coherer can be tuned to many different wavelengths. Marconi was pleased with the degree of selectivity that he had achieved. However, Collins (Thom-Collins, 1908, Part II, p. 28) is less sanguine in his appraisal of Marconi's device, e.g.: "when syntonized to each other, selectivity may be obtained within certain limits."

On April 26 1900, Marconi filed for a patent to control syntonic tuning based upon his improvements of the Lodge technique. He argued that it would allow several stations to operate at the same time without interference. The patent was granted in 1901, and Marconi felt that he had attained commercial control of every important aspect of wireless telegraphy. Lodge claimed, however, that he held the basic patent for tuning wireless apparatus. Lawsuits ensued over a period of years until 1911, when Marconi interests purchased the Lodge patent (Coe, 1943, p. 111).

As Marconi moved forward in developing his apparatus, business grew briskly. On January 25 1899, the Marconi Company signed a lease to refurbish an abandoned silk factory and warehouse in Chelmsford in order to

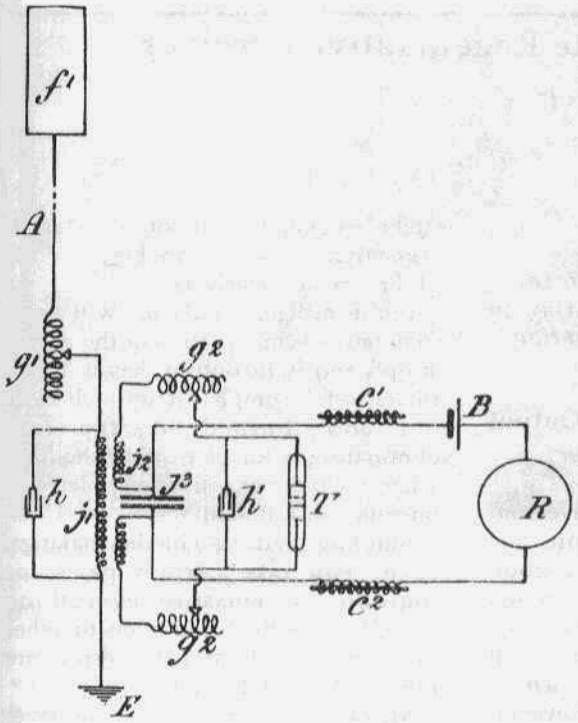

Figure 5

establish a manufacturing plant and warehouse. On July 4 1900, the British Admiralty contracted with him to install his apparatus on 26 of its ships and to build several land and lighthouse stations. Additionally, Lloyd's of London purchased his equipment to communicate with incoming ships for advance cargo reports (Jolly, 1972; Kreuzer & Kreuzer, 1995).

Marconi was only 26 years old early in 1900, and already renowned internationally. The science of wireless was progressing rapidly, however, and he was no longer alone in attempting to evolve a commercially viable system. DeForest and Fessenden, in the United States, Slaby in Germany, Popoff in Russia, and Bose in India were exerting pressure (Wellman, 1952).

Marconi aspired to create a dramatic maritime coup that would attract new customers and convince government and marine officials the world over of the superiority of his wireless system. Most of his sales had been to ships and shore stations, and he believed that he could persuade the Board members of his Company, at their meeting, in December 1900, to go along with his intentions. He told the members that he envisaged powerful land stations on both sides of the ocean; each would have sufficient range to reach the mid-Atlantic, which would ensure that vessels in the busy shipping lanes could be always in contact with one continent or the other, thus averting disasters at sea. Marconi's Board approved the project with little equivocation.

Nonetheless, conventional wisdom at the time thought it fanciful. It was assumed that the useful life of a wireless transmission extended no farther than the horizon. The meager evidence available then seemed to show that signals travel in a straight line past the horizon to be lost in space. No one was aware that long-distance wireless communications are possible because electromagnetic waves are reflected to earth from the ionsphere, a region of rarefied air above the surface of the earth that is ionized by ultraviolet rays from the sun. Marconi, nevertheless, firmly believed that his experiments suggested some phenomenon was causing his transmissions to follow the curvature of the earth, and he willingly risked the fortunes of his company, knowing that proving the pundits wrong also would boost his international stature. ER

Next month Part III

Marconi's Dramatic Moment on Signal Hill: A Retrospective Review

Part Three

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Part III. Marconi's dramatic moment at Signal Hill

Marconi had been somewhat disingenuous with his Board, for his intended coup was not to build simply a powerful spark-gap transmitter in England and America, respectively, each of which would have the capability of sending a signal halfway across the ocean. Hardly! He aimed to build a very powerful transmitter and aerial system on each continent, and each of them would possess the means of spanning the entire Atlantic ocean with its signals. Marconi employed John Ambrose Fleming, University College, London, on December 1, 1900 to design the transmitter. Fleming was the foremost electrical engineer in England, and four years later, while still a Marconi consultant, invented the thermionic valve [British nomenclature for vacuum tube]. R. N. Vyvyan, a construction engineer, was assigned responsibility for building identical transmitters and installing identical aerial systems at Poldu point and in the United States.

Figure 6 presents a diagram of the transmitter that Fleming installed at Poldu point (Vyvyan, 1933, p. 246). Fleming devised a method of "double transformation" to create a spark-gap transmitter that was approximately one-hundred times more powerful than the battery-powered transmitters that Marconi had used heretofore, and at the time it was the most powerful wireless transmitter in existence. According to Bussey (2000), it incorporated a "32-brake-horsepower" oil engine (not shown in Fig. 6) driving a 25-kilowatt 2000 volt 50-cycle alternator ("A" in Fig. 6), which produced a 100 cycle buzz note in the transmitted signal. The output of the alternator was fed to a pair of 20-kilowatt transformers which stepped up the voltage from 2,000 to 20,000 volts ("T" in Figure 6). The oscillation transformers or "jiggers" are marked "J1" and "J2" in Figure 6. The current from transformer "T" charged condenser "C1", a bank of Leyden jars, and discharged through the primary of

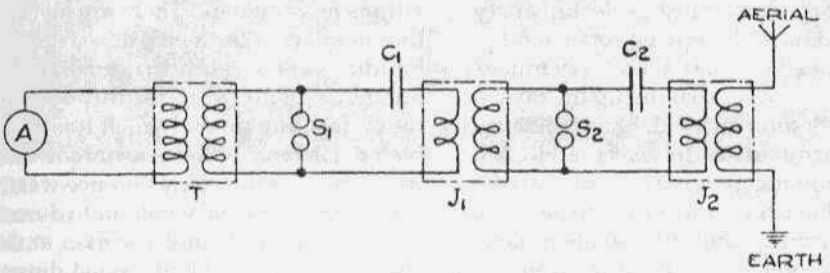

Figure 6.

Figure 7

"J1" across spark gap "S1". The secondary of "J1" is connected to a second spark gap "S2", a second condenser "C2", which is another bank of Leyden jars, and the primary winding of a second oscillation transformer "J2", also across "S2". The secondary of "J2" is in series with the aerial and ground. (Vyvyan, 1933; see also Bussey, 2000, for discussion and pictures of Fleming's huge transformers).

Fleming did not have the transmitter ready until early summer, 1901, because he encountered difficulty developing high-efficiency output coils. Although Fleming had no way of knowing his exact wavelength, he could, at least, influence it by changing the windings on his output coils and adjusting the Leyden jars. Once the transmitter parameters were syntonized to a given wavelength, aerials and a coherer could be tuned roughly to that particular wavelength, which would maximize signal strength at the coherer. [Contemporary scientists estimate that Fleming operated approximately on a wavelength of 366 meters or 820-850 kHz (Bussey, 2000, p. 23; Tarrant, 2001, pp. 62-63).]

Fleming also had to confront the problem of inserting a key in the circuit for sending dots and dashes. A small telegraph key would have been a lethal instrument in the primary of the 2,000 volt alternator, where power in excess of several kilowatts would have to be interrupted. Fleming thus came up with a "ponderous electrical switch to make and break the circuit" (Kreuzer & Kreuzer, 1995; Vyvyan, 1933), which very likely was similar to the one shown in Figure 7 (Thom-Collins, 1908, Part II, p. 17). As of 1901, therefore, the transmitter that Fleming had developed for Marconi could not actually send intelligible messages for two reasons: first, the "switch" a k a "key" was too bulky and dangerous to use speedily, as when sending the letters of Morse code, and second, Fleming was fearful that rapid interruption of power would so strain the alternator, transformers, and condensers that they would burn out.

Marconi met with Vyvyan in early February to discuss his idea for a new long-distance aerial, which like the transmitter, would be the largest and most elaborate ever built, and he was probably too engrossed in design issues to evaluate the concerns that Fleming was raising. Vyvyan questioned whether a physically stable aerial could be built to Marconi's specifications, but incautiously, Marconi ordered on February 12, 1901, that construction begin. The aerial system constituted a ring of 20 wooden masts, 200 feet in height, and 200 feet in diameter. The array was intended to support a conical

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aerial of 400 wires, each wire was insulated at the top and all were connected at the bottom, thus forming an inverted cone. A hut was built in the center of the array to house the transmitter, and the lead wire of the cone entered from the middle of its roof. Each mast was guyed to the next one and to the ground in a radial direction both away from and toward the center of the mast system (Vyvyan, 1933). The mast guys, which were anchored to cement blocks, were divided into short lengths by insulators so that they would not pass electromagnetic waves to ground. Vyvyan believed that stress associated with any one of the masts, which might occur during a storm, would jeopardize the entire assembly (Bussey, 2000; Hall, 1996; Orr, 1985; Vyvyan, 1933).

A few weeks later, once construction of the Poldu projects was progressing satisfactorily, Marconi and Vyvyan sailed for South Wellfleet, Cape Cod, Massachusetts, to make arrangements for a comparable station (Hall, 1996). A finished version of the inverted-cone aerial system is shown in Part 1 (ER, December, 2001, #151, p. 11; see also Vyvyan, 1933, p. 23).

Marconi returned to England in April; Vyvyan remained at Cape Cod to supervise building the second station. He delivered in May a paper on "syntonic wireless telegraphy," at the Society of Arts, London, and experimented with the new apparatus at Poldu through the summer of 1901 (Bussey, 2000). On September 17, a furious storm uprooted the masts at Poldu. The cone aerial was destroyed, and a gaping hole was ripped in the roof of the hut. Marconi abandoned immediately the ill-fated circular array in favor of a modest experimental aerial, thus cutting losses, and allaying growing anxiety among his Board members, who worried that expenditures, for which they may never have anything to show, were mounting astronomically. Marconi's action was fortuitous, too, because, only a few weeks later, a nor'easter demolished the circular array at Cape Cod.

Marconi had an experimental aerial in service by September 26 1901, thanks to the enterprising Kemp. The aerial Marconi and his advisors chose to erect was a vertical fan-shaped array, a design that attained later widespread use in the early twentieth-century. In this instance, a horizontal wire of about 200 feet was stretched between two masts, 150 feet in height. Fifty-four wires, spaced one meter (roughly one yard) apart were insulated and suspended from the horizontal wire. The aerial wires were arranged in a fan shape, and connected together at the lower end, where a single wire entered the repaired roof of the transmitter hut. The entire array looked analogously like a fan, a harp, or an inverted triangle standing on it apex (Thom-Collins, 1908; Vyvyan, 1933; see a picture of the array in QST, December, 2001, p. 45).

Marconi was encouraged by the distances that he could cover with the transmitter and vertical-fan aerial at Poldu. But given the catastrophe at Cape Cod, and the likelihood that the substitute was not as efficient as the cone-shaped aerial would have been, he made two major compromises in his ongoing struggle to conduct a transatlantic test. First he chose to try it from Newfoundland instead of Cap Cod, which would enable him to shorten the distance of the transmission by several hundred miles; second, not having an alternative to the station at Cape Cod, he decided that signals would be sent only one-way-from the powerful Poldu transmitter to his coherer in Newfoundland.

Marconi was eager to bolster the morale of his Board members with good news, and he knew that a successful transatlantic transmission would invigorate them, especially since they

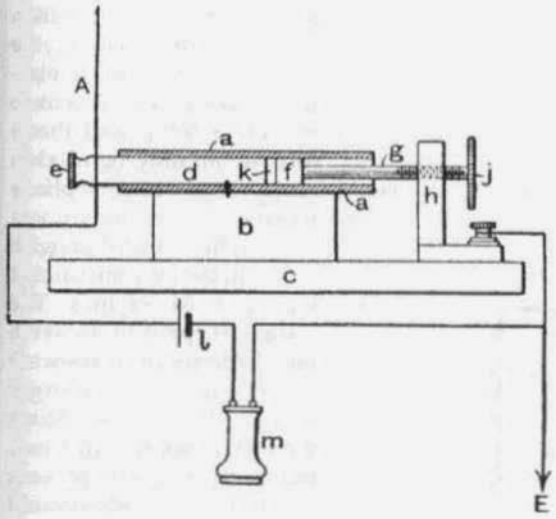

Figure 8

had no idea that was what he hoped to achieve. He kept his goal to himself, however, for three reasons: he did not want to raise the expectations of his Board after so much disappointment had arisen already, he knew a failure would level a crushing blow to his growing stature, and he was uncertain about how authorities in Newfoundland would respond to his overtures.

But Marconi was pressed for time. The onset of the harsh Newfoundland winter was fast approaching, and he was aware that he had to act promptly if he was to have anything to show in 1901 for his investment in time and resources (Jolly, 1972; Masini, 1995; Tarrant, 2001). Consequently, Marconi, Kemp, and Percy W. Paget, a trusted technician who had joined him two years earlier, sailed from Liverpool on the S.S. Sardinian, November 25 1901, bound not for Cape Cod but St. John's. They brought with them several tanks of hydrogen gas cylinders for inflating cotton-silk balloons, 14 feet in diameter with a capacity of 1,400 cubic feet, and six hexagonal kites, which were made of bamboo and silk and measured 9 feet by 7 feet (Bussey, 2000; Hawks, 1927; Tarrant, 2001). Their baggage also included aerial wire, Billy coil, telephone receiver, and batteries; an improved Branly/Lodge coherer including a relay, tapper, and inker as accessories; and at the last moment, almost as an after thought, a self-restoring, mercury coherer.

Paolo Castelli, a semaphorist in the Italian Navy is recognized as having invented in 1899-1900 a new mercury coherer (Masini, 1995, p. 176). Marconi was aware of it. The Italian Navy was using the coherer along with Marconi's syntonic system, which offended him because his patent was being infringed. Eventually, the Italian Navy sent to London his old friend, Solari, to make amends. Solari was then an electrical engineer and Lieutenant in the Italian Navy; he had been Marconi's boyhood compatriot when they studied physics together, and during the early 1900s rose to become one of Marconi's trusted colleagues. He arrived about the time that Marconi was preparing to leave for Newfoundland, and as a gift from the Italian Navy, he gave him a mercury coherer.

A diagram of Castelli's self-restoring, Italian Navy coherer—a precursor of the galena crystal detector—is shown in Figure 8 (Fleming, 1919, p. 378). It is also known as the "Solari coherer," since in a letter to the London Times, July 3 1902, Solari claimed that he had invented it (Fleming, 1919, p. 377). In the diagram, the aerial "A" is connected to one terminal of the coherer [not shown explicitly in Figure 8], and in turn, to battery "L" in series with one terminal of the telephone receiver "m". The other terminal of the receiver is connected to the other terminal of the

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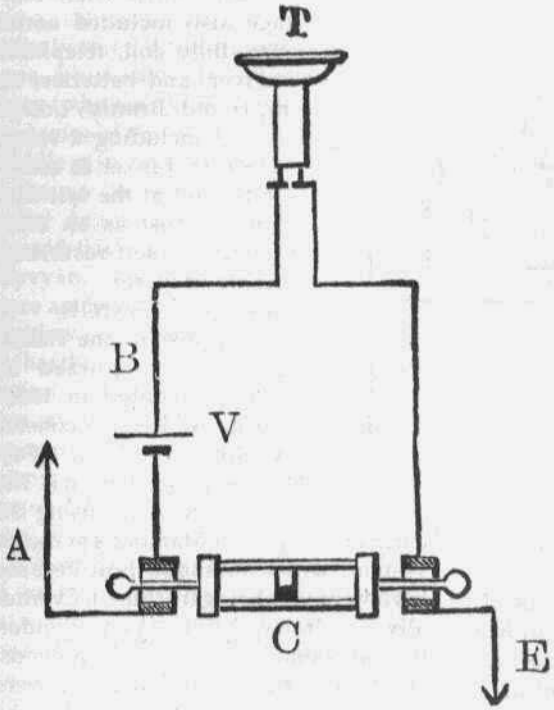

Figure 9

coherer and to ground "E". The mercury coherer is comprised of a thin glass shell "a", carbon plug "d" and head "e", mercury globule "k", iron plug "f", adjusting screw "g" and thumbscrew "j", base "C", and vertical holder "h".

As shown in Figure 9, the mercury coherer is placed in series with a battery and a telephone receiver. Reception of an electric wave causes a sudden decrease in the resistance between the carbon and iron electrodes, and a sharp click is heard in the telephone. When the coherer is properly adjusted, it returns immediately to its original state of high resistance. When the key of a spark gap transmitter is pressed, a buzz sound in the receiver coincides with activation of the arcking sparks, which allows for ready distinction of dots and dashes. Whereas the mercury coherer is much easier to operate than the metal filings coherer, the reaction of mercury to electric waves is insufficient to operate a relay, and therefore, it can only be used in conjunction with a telephone receiver.

Marconi's reunion with Solari in the autumn of 1901 was a stroke of luck. The inherent problems with metal-filings coherers were becoming increasingly distressing to him. Ships were his major constituency, but heaving in bumpy seas magnified a ship's natural vibrations, which subjected the metal filings to mechanical shocks that disrupted reception. This problem, augmented by the inconstancy of the tapper, convinced him that another type of coherer must be devised. Marconi hunted through the scientific literature until he came across the work of Ernest Rutherford, a distinguished, New Zealand physicist, who had recently migrated to England, who received the Nobel Prize in chemistry in 1908, and who later was to become the founder of nuclear physics. In 1894-1895, Rutherford, investigating a rudimentary idea for a detector using a moving bobbin of fine wire and a magnetized steel needle, discovered interaction between electric waves and needle magnetization. Marconi found Rutherford's idea of a magnetic detector enormously attractive, and he constructed prototypical models even while the transatlantic project was foremost in his mind. After he returned triumphantly from Signal Hill, he shielded himself for a few months from all but essential social interaction, while working tirelessly to perfect it.

Marconi's version of a magnetic detector was soon operational, and he applied for a patent on June 2, 1902. Rutherford, as one might expect, was furious that Marconi had preempted the priority of his discovery, harbored enduring, deep-seated bitterness toward him, and tangled with him in litigation for several years.

Jolly (1972, p. 104) observes that when Marconi and his two staff members arrived in Newfoundland "with balloons and kites to raise the aerial wire as high as possible . . . it was a long way from the grandiose scale on which the '"great thing"' had been planned. . . . The little party which sailed from Liverpool, with hastily gathered bits and pieces for an aerial, was a lot closer to the style of the old Villa Grifone days than Marconi and his directors would have wished after all the secret planning and the vast expense."

Marconi certainly maintained his subterfuge in St. John's. He informed media and government authorities that his intention was to try to establish contact with passing wireless-equipped ships. The Canadians were thrilled to have Marconi on site, and they encouraged him to set up his apparatus on Signal Hill, a flattened, rocky peak of high land, beside the harbor, that juts into the water a few hundred feet above the Atlantic. Cabot Tower, erected in honor of John Cabot who arrived in Newfoundland in 1497, shared the site with an abandoned hospital for communicable diseases, and an old army barracks.

The cold in December on Signal Hill is relentless; frequent rain turns to ice as it falls, and incessant wind whips everything about, but the terrain provided a requisite plateau for flying balloons and kites. Marconi, for his receiving station, occupied a couple of drafty rooms, with a stovepipe heater, at the back of the old hospital. On Monday, December 9 1901, a local company was hired to bury zinc plates in the frozen rocks for a ground connection, and accompanied by a photographer, Marconi and his crew, which now included a couple of assistants from St. John's, began to set up their apparatus. The aerial wire passed over a window sill to a nearby telephone pole, where it would be attached to an aerial wire to be elevated by a balloon or kite.

On Tuesday, December 10, the team flew a kite with 600 feet of aerial wire as a preliminary test. Three men barely held the huge contraption steady enough to get it aloft; it twisted and bucked in a heavy wind, but they managed to reel it in safely.

On Wednesday, December 11, Poldu operators were scheduled to begin transmitting daily the Morse code letter "S" (dot, dot, dot) from 3:00 pm to 6:00 pm London time (11:30 am to 2:30 pm St. John's time). The simple letter "S" was chosen on the basis of Fleming's concern that rapid keying of the transmitter would endanger its transformers (see discussion, Part III, above). Bussey (2000, p. 48) also observes, "it assured that the signal could be read on a Morse inker recorder through atmospherics which tended to run all the dots and dashes into each other." Marconi preferred the balloon to a kite, since he hoped that it would hold the aerial height relatively constant, thus stabilizing resonant circuits, so that he could both employ his syntonic system and record the Poldu signals on his Morse inker. Therefore, early in the afternoon, for the first transatlantic test, a 14-foot balloon was inflated with about 1,000 cubic feet of hydrogen; however, scarcely after the beast was in the air, a swift gale ripped it loose from its mooring, allowing it to float off in the clouds. With his aerial gone Marconi was forced to give up for the day. ER

Part 4, the conclusion, next month

Marconi's Dramatic Moment on Signal Hill: A Retrospective Review

Part Four, Conclusion

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The next morning, Thursday, December 12, 1901, a strong wind dictated use of a kite instead of a balloon. The first kite sent aloft broke away, as the balloon had the day before. Kemp observed that had he been positioned differently, "I should have gone with it as its speed was like a shot out of a gun" (Bussey, 2000, p. 49). The crew was able to keep a second kite up. It looped, bobbed, dove, and righted itself while they struggled to extend it to about 400 feet. The erratic height and length of the aerial compromised prospects of keeping the syntonic system in resonance. Marconi, for that reason turned to Solari's mercury coherer, across which he attached a telephone receiver and battery connected in series (see Figure 9). The Branly/Lodge coherer with its syntonic mechanisms, relay, tapper, and inker accessories, which Marconi had so painstakingly developed, were "out the window." The good news was that the untuned coherer and telephone receiver combination would be more likely than the latter to copy the Poldu signal should it be very weak. The bad news was that Marconi would not acquire ostensible proof via inker tape that the Poldu signal had really been heard.

The different items of receiving equipment that Marconi brought with him to Signal Hill are shown in Figures 10-15: the greatly improved Branly/Lodge coherer, (Figure 10); the Morse inker, (Figure 11); the mercury coherer, (Figure 12); the telephone receiver, (Figure 13); the Billy coil, (Figure 14); and a kite, (Figure 15).

According to statements by both Kemp and Marconi, the crew kept the kite aloft for three hours and "at 12:30 pm, 1:10 pm, and 2:20 pm the prearranged signals from Poldu were received . . . " (Bussey, 2000, pp. 49-50). Only Marconi and Kemp heard them on the 12th—no one else was in the room. The signals were heard again on Friday, December 13th, but reception was relatively brief and too indistinct to be confirmed with any certainty. Marconi discontinued the tests on Saturday, December 14, 1901, because of harsh weather.

A noteworthy question arises as to the nature of the signal to which Marconi and Kemp listened on December 12 and 13, 1901. Did they hear with the telephone receiver three "dots" signifying the letter "S" or merely three clicks? The formation of a "dot" should have produced in the telephone receiver a "click-buzz-click," briefly spaced, for each of the three code elements of the letter "S," that is, a total of six clicks bracketing three buzzes, respectively. Merely listening to three clicks would signify nothing intelligible. Credible biographers emphasize that Marconi heard three dots; they ignore whether he also heard clicks (Jolly, 1972; Kreuzer & Kreuzer, 1995; Vyvyan, 1933). In contrast, (Wellman, 1952, p. 33) says Marconi heard "three fast clicks in the receiver." Jacobs (1961, p. 31) states "the three faint clicks heard in the telephone receiver was the Morse letter

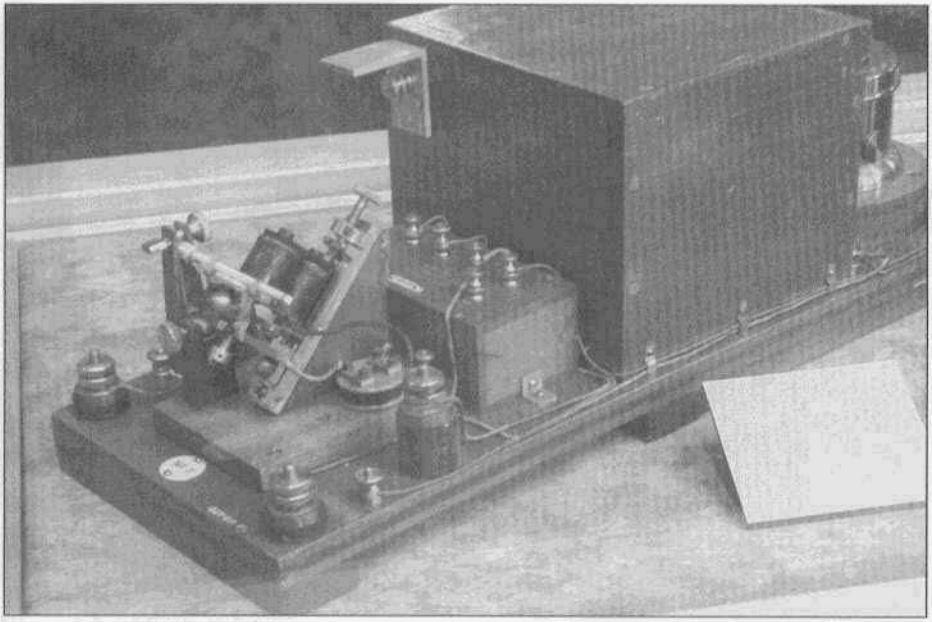

Figure 10. Branly/Lodge coherer.

"S," and Tarrant (2001, p. 56) reports that Marconi "heard three faint clicks in the receiver designating in Morse Code the letter `S.'" Bussey (2000, p. 49) quotes Marconi as saying "`unmistakably, the three sharp little clicks corresponding to three dots, sounded several times in my ear . . .'"

Marconi himself may be our best authority. The sharpest, strongest sound emanating from a mercury coherer whenever an electric wave is received is that of the onset click in the telephone receiver. Given the ferocious local storms, the buzz and offset click accompanying each first click may have been virtually masked by random atmospheric noise. Marconi acknowledges that each click was faint, but the fact that clicks were sent rhythmically in sets of three and that he and Kemp probably heard each buzz almost imperceptibly indicates that they assumed correctly that they were listening to dots corresponding to the Morse letter "S."

A second query, and perhaps the most puzzling, deals with Marconi's strange laxity in establishing confirmation of the signals from Poldu. The importance of the event to his Company and to him cannot be overestimated. He regarded it as a defining moment in the seven years that he had devoted to improving wireless technology. His Company had invested about $250,000 in the experiment. He had convinced it that he would establish a transatlantic wireless system, and the Poldu to Signal Hill transmissions revealed that the system would be possible. Although many physicists and mathematicians believed that signals travel in a straight line across the horizon, his data proved them wrong. But the only evidence that he possessed, besides his own word, was Kemp's corroboration. His Morse inker would have provided definite proof, except that horrendous weather did not permit him to use the coherer to which it was attached. Why then, on December 12, when he and Kemp heard

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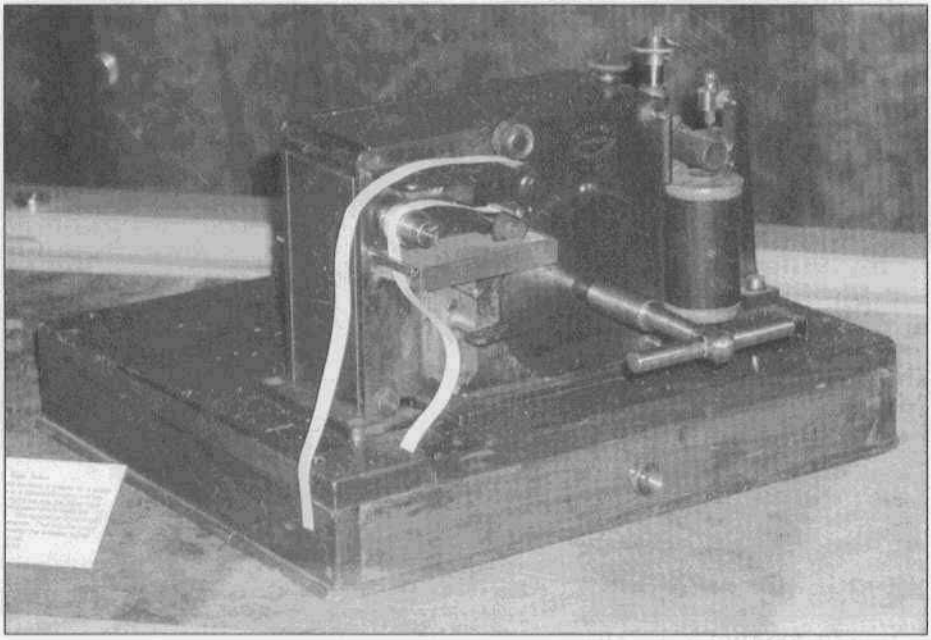

Figure 11. Morse inker.

the clicks reasonably well, did they not call others to come inside and listen? One certainly did not have to be familiar with the Morse code to discern three rhythmic clicks in a telephone receiver. Where was his photographer, members of his team of technicians, etc.? An opportunity for strong proof bolstered by additional witnesses was at hand, but Marconi neglected to take advantage of it.

On December 14, 1901, Marconi released the news that the Poldu signal had been heard in Newfoundland. The media throughout the world was unsurprisingly ecstatic. Marconi basked in the attention. He shrugged off critics who argued that all he heard was random atmospheric electrical noises, and, perhaps in too euphoric a mood, he informed Newfoundland authorities that he intended to construct a wireless station as powerful as the one at Poldu on either Signal Hill or a nearby Cape. He would be leaving his assistants to erect a tower and prepare the site for the installation of a transmitter. As Marconi's plans approached pretentious proportions, the Anglo-American Telegraph Company of Newfoundland, which held a monopoly on telegraph enterprises in the Colony, decided belatedly that it did not want Marconi around. On December 16, 1901, the Telegraph Company informed Marconi that it had obtained an injunction that required him to cease experimenting in Newfoundland.

Marconi's legal problems in Newfoundland, however, failed to impede his progress. On December 24, 1901—less than three weeks after he had arrived in Newfoundland—he sent Paget with the apparatus that he had used on Signal Hill to England, where it was set aside for one-hundred years. He departed St. John's a few days later for Ottawa, where he obtained from the Canadian government a grant to build a wireless station at Glace Bay, in northeastern Nova Scotia. After signing contracts in Canada, he left for New

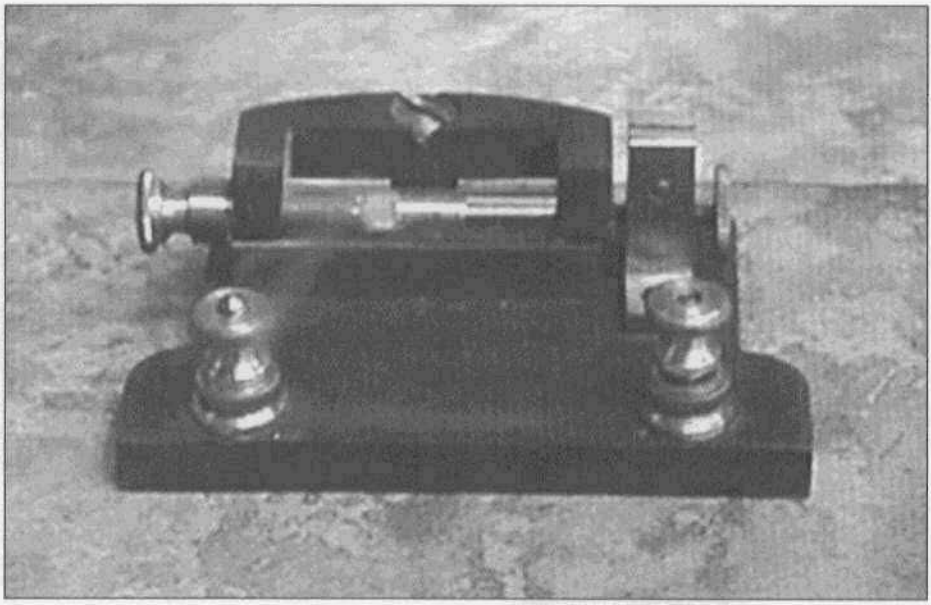

Figure 12. Mercery Coherer

York City where on January 13, 1902, he was guest of honor at a gala dinner of the American Institute of Electrical Engineers. Over 300 distinguished guests feted the 27-year-old, applied-scientist to celebrate his momentous success in advancing wireless technology. The roster of dignitaries who paid tribute to Marconi included Charles Steinmetz, Elihu Thomson, Alexander Graham Bell, Michael Pupin, and Frank Sprague (Bussey, 2000; Jolly, 1972; Kreuzer & Kreuzer, 1995).

Thomas Edison and Nikola Tesla were absent conspicuously from the dinner. Although both sent congratulatory telegrams, each had responded less than positively upon first learning of Marconi's transatlantic triumph. Edison had characterized the event in the press as a "newspaper fake;" however, he recanted shortly thereafter, saying that he had faith in Marconi's integrity and that his word was sufficient for accepting his claim. Tesla, in contrast, nurtured a simmering hostility toward Marconi, whom he contended was infringing upon his patents. One afternoon, in mid-December 1901, Tesla and a friend were taking a stroll. "'Looks like Marconi got the jump on you,'" said the friend. "'Marconi is a good fellow,' replied Tesla. 'Let him continue. He is using seventeen of my patents'" (Cheney, 1981, p. 161). Tesla eventually sued Marconi in 1915; as Cheney (1981, p. 181) reports, "the war of wireless patents was waged back and forth for decades, and little wonder that confusion ensued."

Marconi's stature in history

When Marconi died prematurely in Rome from heart disease on July 20, 1937, radio broadcast and commercial stations world wide paused transmitting for a moment of respectful silence. Hugo Gernsback published a glowing eulogy to Marconi a few weeks after his death. Gernsback, pioneer editor of such twentieth-century radio publications as *Electrical Experimenter, Radio Craft, Radio News*, and *Shortwave Craft*, etc., is rightfully acknowledged to have been the foremost radio

continued next page

Figure 13. Telephone Receiver

journalist of the era. Gernsback exulted from his editorship that Marconi "will no doubt go down in history . . . as great or greater than any other benefactor who ever lived" (Gernsback, 1937, p. 197).

Gernsback insisted that the world owed Marconi a staggering debt. He was responsible for saving tens of thousands of lives that would have perished in the sea. Further, through his contributions to wireless, and later the radio age, he "brought to life not only a huge industry, but has brought all humans closer together, . . . and lately in broadcasting has given the human voice wings such as it never before dreamt of having" (Gernsback, 1937, p. 197).

Gernsback also declared: "It should not be forgotten that it took a tremendous amount of courage and belief in himself to think that a new and untried system of transmitting electromagnetic waves over almost 2,000 miles of curved ocean surface was within the realm of even a remote possibility. That took more than courage. It was really a supreme heroic gesture, and it is probably for this one outstanding accomplishment, more than any other, that the world is paying homage to the dead inventor today" (Gernsback, 1937, p. 197). Finally, Gernsback said that Marconi "was able to make his genius helpful to others, as no other man had done upon so wide a scale. Never before has the lifetime of a single man been so identified with a change in the conditions of life on the globe, of which he was the most conspicuous creator" (Gernsback, 1937, p.203).

Gernsback was predisposed to wild gyrations of hyperbole, as readers of his publications are aware. However, in this instance, Marconi's biographers share uniformly an equally strong reverence for him. All the biographic portraits, of which I am aware, are written in hagiographic style, that is, as if Marconi qualifies for sainthood. Their data are comprised of interviews and sketchy diaries obtained from colleagues, Marconi's speeches and interviews, and secondary sources such as company documents and correspondence. Accounts and details of Marconi's numerous experiments are virtually nonexistent. What is known about his formative years is largely hearsay. Emilo Segre, a 1959 Nobel Laureate in physics, stated recently that "Marconi was interested in Patent Applications, not scientific papers, and

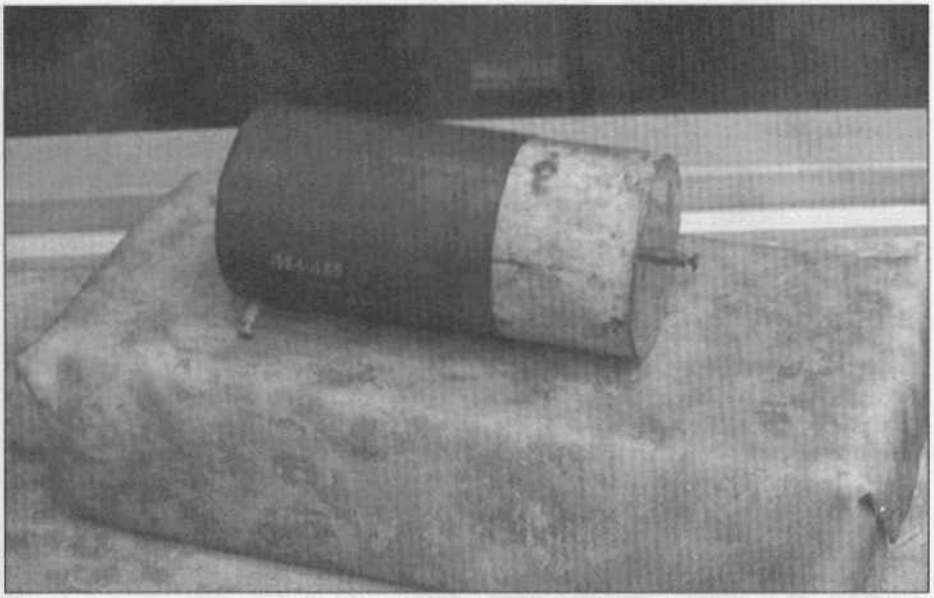

Figure 14. Billy Coil

for this reason he was rather secretive about his procedures, a habit that has presented additional difficulties for anyone trying to reconstruct his way of methodology" (from Masini, 1995, p. 10).

Fortunately, as Marconi's fame spread, especially subsequent to the late 1890s, he realized that both he and his achievements would someday be of significant historical value, so he surrounded himself with photographers wherever he went. Facts and events associated with Marconi tend to be embellished and biased toward keeping a halo hovering brightly over his image, but the voluminous photographs furnish an antidote to the intrusive fiction.

After idolization is peeled away from depictions of Marconi's personal and professional life, the substratum exposed still suggests that he exemplifies the characteristics of a highly creative person. On the one hand, his upbringing shaped his native intelligence to reflect an inquisitive, exploratory, visionary mind. His self-training in the applied and technical aspects of physics led him to see solutions to problems whereas others saw dead-ends. Moreover, Marconi's creativity reflects a genius of endeavor; he attacked problems with such prodigious vigor that he was always a step ahead of his competitors; no issue seemed insurmountable to him and fear of failure seemed not in his constitution.

On the other hand, truly creative persons are those who find ways to express themselves in ways that will have profound impact upon society. Marconi's professional career spanned 43 years, from 1894 to 1937. The transatlantic event in 1901 represented for the twenty-seven year-old incremental progression only seven years into a fast-paced, professional life that produced a Nobel Prize in 1909, and a Company that rose during his lifetime to dominate worldwide marketing in maritime electronics. Marconi was extraordinarily successful in focusing his genius zealously in a

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Marconi from page 9

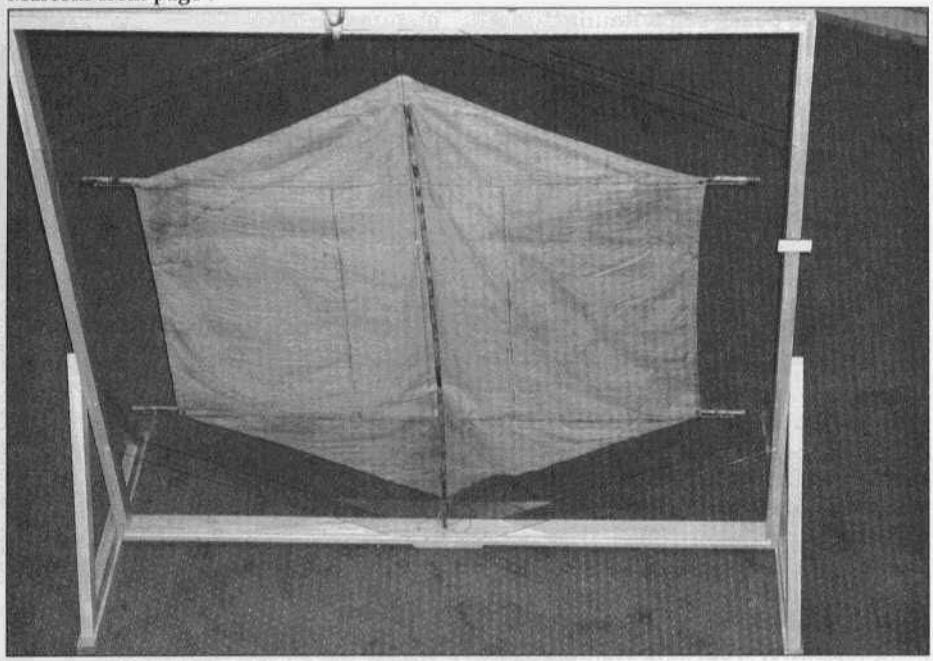

Figure 15. Kite

particular technological niche-electronics—one that he helped prosper from inconspicuous beginnings into a practical usefulness that influenced major aspects of twentieth-century culture and brought about immeasurable benefits to humankind.

Creativity, of course, often spawns excesses. Marconi claimed in patents that he had "invented," but his endeavors represented integration, innovation, and application. He brazenly and deliberately lifted ideas and experimental models from analytic laboratory scientists, and he patented them shamelessly on the premise that he had improved upon them, which precipitated extensive litigation with the original inventors. Marconi's biographers suggest that modesty was one of his cardinal traits; perhaps so, yet part of his deference may have been his manner of deflecting the wrath of the scientists whom he angered.

The transatlantic signal sent from Poldu to Signal Hill occurred ironically with apparatus that Marconi had not even improved upon; Fleming had designed the spark-gap transmitter, Vyvyan had built it, and Solari had furnished the mercury coherer. Is history really warranted in recording the happening as "a supreme heroic gesture"? Is it more realistic to view the event as a transitional experiment in Marconi's well-calculated, step-by-step strategy to corner the wireless market? The retrospective review presented here points to a negative response to the first query and an affirmative answer to the second. Marconi himself saw the transatlantic test as an experiment and he was definitely the moving force behind it, as he was of countless experiments that he had instigated earlier and would promote for thirty-six more years. Encomiums have showered upon him for 100 years. The preponderance of evidence on which they are based supports those who assert that he "is justly called the inventor of radio-telegraphy" (Hogan,

1924, p. 12). It does not support anyone who lauds Marconi as the inventor of radio. ER

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Postscript:

I am indebted to George H. Fathauer, Paul T. Finell, W7EFQ, and Lee O. Heflinger, W6WZV, for helping me as I prepared this manuscript. The topics of spark-gap transmitters and coherers are today among the most arcane and perplexing in the history of electronics. These distinguished electronic scientists drew upon their vast theoretical and practical knowledge to help me deduce the probable conceptual perspectives and methodologies of our forbears. I thank them gratefully for the insights that I have attained. I am responsible, nevertheless, for the interpretations and assertions made herein.

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